

**U.S. DEPARTMENT OF THE INTERIOR  
BUREAU OF LAND MANAGEMENT - ALASKA  
DIVISION OF MINERAL RESOURCES  
BRANCH OF MINERAL ASSESSMENT**

**TETLIN  
NATIONAL WILDLIFE REFUGE  
OIL AND GAS ASSESSMENT**

**by**

**Robert Basclé**

**William Diel**

**Richard Foland**

**Aden Seidlitz**

**James Borkoski**

**September 1988**

## TABLE OF CONTENTS

	<u>Page</u>
Executive Summary.....	i
Illustrations.....	ii
Introduction.....	1
Location and Physiography.....	1
History of Geologic Exploration.....	5
Stratigraphy and Lithology.....	6
Structural Geology.....	15
Tectonic Setting.....	16
Geologic History.....	21
Description of Oil and Gas Resources.....	24
Known Oil and Gas Fields (Regional).....	24
Known Oil and Gas Fields (Local).....	25
Potential for Oil and Gas Occurrence.....	25
Typical Oil and Gas Development Scenario.....	27
Production Scenario.....	27
Economic Potential.....	29
Bibliography.....	31
Appendix A - MOU Between USFWS and BLM.....	A1
Appendix B - BLM's Mineral Potential Classification System.....	B1

## Illustrations

	<u>Page</u>
Plate 1. Geologic map of Tetlin NWR	
Figure 1. Location of Tetlin NWR.....	2
Figure 2. Physiographic section map of Tetlin NWR.....	3
Figure 3. Stratigraphic column of Tetlin NWR.....	7
Figure 4. Cross sections of Tetlin NWR.....	18
Figure 5. Diagrammatic cross sections showing structure and tectonic history south of Denali fault.....	18
Figure 6. Lithotectonic terrane map of Tetlin NWR.....	19
Figure 7. Hydrocarbon occurrence potential map of Tetlin NWR.....	26
Figure 8. Hydrocarbon development potential map of Tetlin NWR.....	30

## Executive Summary

The Tetlin National Wildlife Refuge and nearby area have attracted little interest for oil and gas exploration. No wells have been drilled within the refuge boundary.

Tetlin NWR has one area of LOW potential for the occurrence of oil and gas and the remainder of the refuge has NO potential. The area of LOW potential (BLM mineral occurrence potential classification L/A) lies in the southwest corner of the refuge between the boundary and the Denali fault. It covers approximately 45,000 acres of refuge land. The remainder of the refuge, approximately 879,000 acres, has NO potential for the occurrence of a concentration of oil and gas resources. This area has a BLM mineral occurrence potential classification of O/D.

Tetlin NWR has no economic or development potential for oil and gas resources for at least the next 25 years.

TETLIN NATIONAL WILDLIFE REFUGE  
OIL AND GAS ASSESSMENT

Introduction:

The U.S. Bureau of Land Management (BLM) has entered into a Memorandum of Understanding with the U.S. Fish and Wildlife Service (FWS) to develop an oil and gas resource assessment for each of the 16 National Wildlife Refuges in the State of Alaska (see Appendix A).

This report will assist the FWS in preparing a "comprehensive conservation plan" for the Tetlin National Wildlife Refuge. It identifies those areas within the refuge which are favorable for the occurrence of oil and gas resources.

Location and Physiography:

The Tetlin NWR, situated on the north side of the Alaska Range at the head of the Tanana River Valley, is characterized primarily by northwest trending, low rolling hills and broad, flat plains. Located north of the Wrangell-St. Elias National Park and Preserve, and south of the Yukon-Tanana upland, the Tetlin refuge borders the Mentasta Mountains-Tetlin Reserve in the west and the Canadian border-Alaska Highway in the east (Figure 1). Tetlin NWR lies within the Northern Plateau Province and the Alaska-Aleutian Province of the Intermontane Plateau Division of the North American Cordillera (Wahrhaftig, 1965). Two major physiographic sections overlie the 924,000 acre refuge: the rugged glaciated mountains of the Eastern Alaska Range section and the Northway-Tanacross Lowlands section (Wahrhaftig, 1965) (Figure 2). The Yukon-Tanana upland, a physiographic section characterized by unglaciated, maturely dissected mountains, figures prominently to the north, outside refuge boundaries.

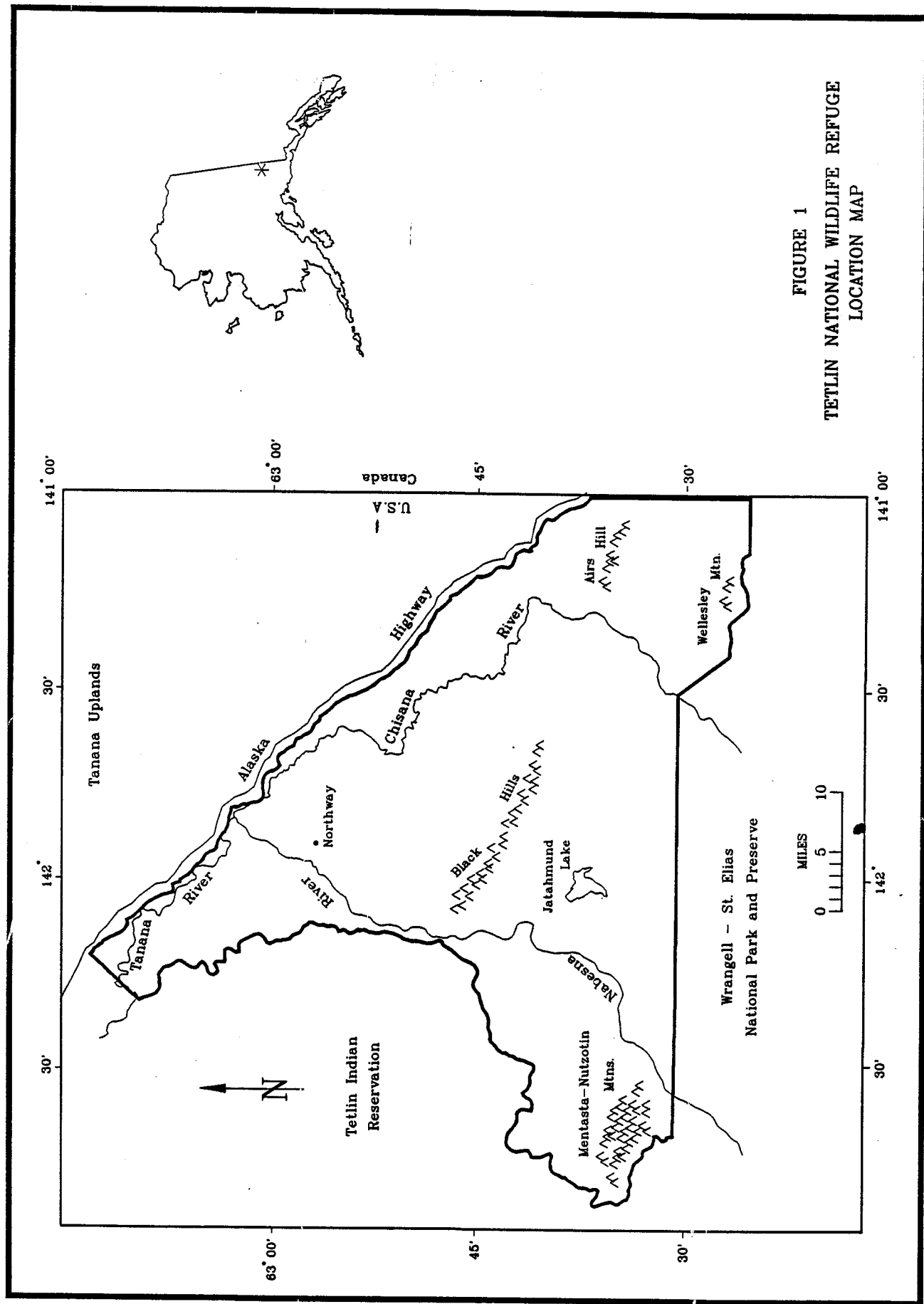


FIGURE 1  
TETLIN NATIONAL WILDLIFE REFUGE  
LOCATION MAP

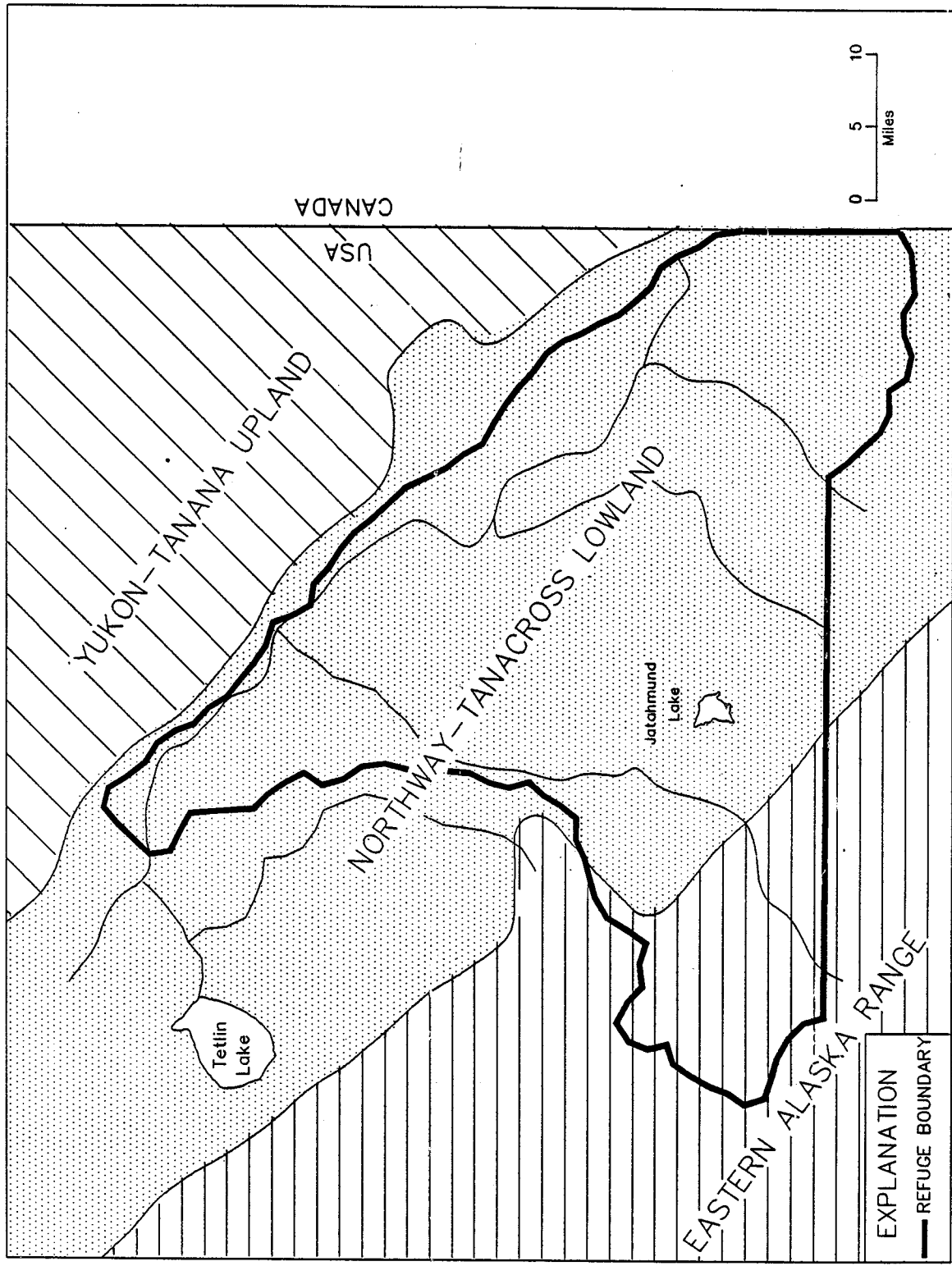


Figure 2. Major physiographic sections of Tetlin NWR (from Wahrhaftig, 1965).

North of the centrally located Black Hills are refuge lowlands comprised chiefly of floodplain alluvium, fluviolacustrine deposits and sand dunes. These deposits are part of the Upper Tanana basin described by Dibona and Kirschner (1984). Elevations average about 1,800 feet (550 m) and the landscape supports numerous lakes and ponds as well as swamps with abundant organic matter. Ancient sands, too heavy to be carried long distances by wind, formed dunes up to ten feet in height. These eolian dune fields are now completely stabilized and occupy areas along the floodplains of the upper Chisana and lower Tanana rivers.

Post-glacial alluvium and pond deposits underlain by extensive ground moraines of the ancestral Nabesna and Chisana glaciers, occupy a large area south of the Black Hills. The deposition of morainal material by former glaciers, combined with the areas close proximity to the Mentasta-Nutzotin Mountains, have contributed to the pediment's average elevation of 2,200 feet (670 m). These alluvial and glacial deposit also contain Jatahmund Lake, the largest body of water within the Tetlin Refuge.

Portions of the Mentasta Mountains, an extension of the eastern Alaska Range, rise in the southwest corner of the refuge. A maximum relief of 5,200 feet (1,585 m) exists between these mountains and the floodplain of the Nabesna River.

Along the southeastern refuge border, between the Canadian Forder and the Chisana River, are a group of gently sloping hills covered with a mixture of colluvium and alluvium. Surrounding the base of these hills are deposits similar to those occupying the lowlands (eolian, fluviolacustrine and alluvial) as well as morainal material deposited by former glaciers. Elevations average about 2,500 feet (760 m) with Wellesley Mountain forming the highest peak at 4,800 feet (1,460 m).



The Nabesna and Chisana Rivers, the two major drainages flowing through the refuge, form at the base of their respective glaciers located 25 miles (40 km) to the south in the Wrangell Mountains. Flowing swiftly in their upper reaches, these glacial waters have cut narrow, steep-walled valleys through the Mentasta and Nutzotin Mountains. Shifting within their flood-plains, the rivers flow in braided channels as they move gradually toward the broad, open valley of the refuge. During the summer months, these rivers are capable of transporting large volumes of rock debris, sand, and silt. The Nabesna and Chisana Rivers merge to form the headwaters of the Tanana River in the northeastern part of the refuge.

#### History of Geologic Exploration:

During the field seasons of 1898 and 1899, W. J. Peters and A. H. Brooks conducted the first geologic investigations of this region. Representing the U.S. Geological Survey (USGS), these geologists made observations along a route that started near the White River, 50 miles (75 km) southeast of the Tetlin Refuge. The party traveled eastward across the Chisana River in the Nutzotin Mountains, then northward down the Nabesna River to its junction with the Chisana where it forms the Tanana River.

An expedition led by Oscar Rohn reached the headwaters of the Chisana River by way of the Wrangell Mountains during the field season of 1899. Prompted by the lack of available scientific and geographic information on this region, Rohn recorded observations that later assisted prospectors and helped further the development of the territory.

More comprehensive geologic studies, which furnished the groundwork of information for subsequent investigations, were carried out by the USGS in 1902 by F. C. Schrader and in 1908 by Adolf Knopf, S. R. Capps and F. H. Moffit. Schrader conducted a geologic and topographic reconnaissance south of the Nutzotin Mountains, between the Gulkana and Chisana Rivers.

Knopf, Capps, and Moffit carried out field studies in an area between the Nabesna and White Rivers and along the northeastern slope of the Wrangell Mountains. The party set out to determine what progress had been made in developing the mineral resources of the district and to gather information concerning the occurrence of ore bodies. Results of these studies served as the principal sources of information on this district for a number of years.

The discovery of gold placers in the Chisana district during the summer of 1913 captured the attention of the scientific community. In 1914, S. R. Capps conducted geologic surveys in this area, known as the Chisana-White Mountain district.

F. H. Moffit, with the help of several field geologists, conducted a number of geologic investigations between 1929 and 1942. This comprehensive study, published in 1954, extended the topographic and geologic knowledge of this remote part of Alaska. More recently, geologic maps of both the Tanacross (Foster, 1970) and Nabesna (Richter, 1976) quadrangles were completed in the 1970s. Other geologic surveys, conducted by state and federal scientists, have produced aeromagnetic, gravity, and geochemical maps as well as a variety of geologic reports concerning the history, structure, and tectonic framework of this region.

#### Stratigraphy and Lithology:

Rocks within the Tetlin NWR range in age from Precambrian(?) to Quaternary. Figure 3 shows the age and stratigraphic sequence of the rock units identified within the study area. Figure 4 represents cross sections of the southwest and southeast portions of the refuge and aid in displaying internal structural features and relationships between rock assemblages.

AGE	STRATIGRAPHIC UNIT
QUATERNARY	Undivided Alluvium and Fan Deposits, Glacial Drift, Sand Dunes, Rock Glacier Deposits, Landslide Deposits, Fluvio-lacustrine and Colluvium.
TERTIARY OR CRETACEOUS	Conglomerate, Conglomeratic Sandstone, and Sandstone.
MIDDLE CRETACEOUS	Gardiner Creek Pluton, Cheslina Pluton, and Tetlin Phase of Tok-Tetlin Pluton. (Granodiorite, Quartz Monzonite)
CRETACEOUS(?)	Undifferentiated Plutonic Rocks
	Serpentinite, Serpentinized Peridotite, and Dunite.
CRETACEOUS to JURASSIC	Argillite, Graywacke, Siltstone, Mudstone, Conglomerate, and Impure Limestone. (Marine Sedimentary Rocks)
DEVONIAN	Andesitic Volcanic Rocks and Basalt Flows. (Greenstone)
	Limestone (Recrystallized)
	Phyllite and Metaconglomerate.
	Diorite and Gabbro – intruded into metamorphic rocks of the Phyllite and Schist unit.
	Phyllite, Quartzite, Calcareous Quartzite, Porcellanite, Calcareous Quartz-Mica Schist, and Marble. (Marine Metasedimentary Rocks)
PALEOZOIC	Schist, Quartzite, Chert, Metaconglomerate, Phyllite, and Schistose Greenstone.
LOWER(?) PALEOZOIC	Quartz-Mica Schist
PALEOZOIC and (or) PRECAMBRIAN	Gneiss, Schist, and Quartzite.

Figure 3. Stratigraphic column of Tetlin NWR  
(compiled from Foster, 1970 and Richter, 1976).

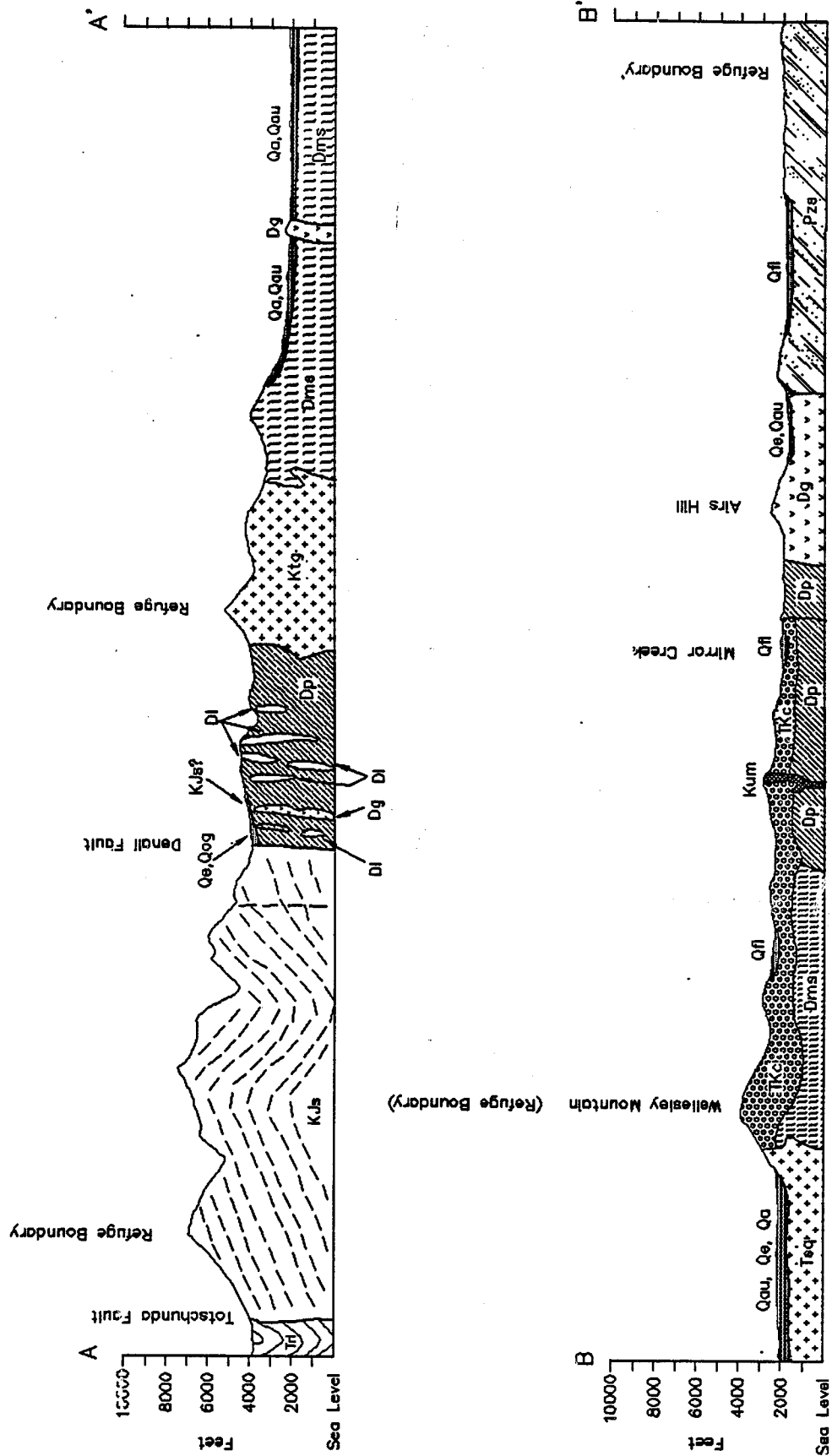


Figure 4. Cross section A-A' (southwest-northeast) and B-B' (south-north) of Tetlin NWR. Vertical scale 1:125,000 (2X Exag.). (Modified from Richter, 1976).

## Paleozoic and (or) Precambrian

Moderate to high grade (amphibolite facies) polymetamorphic rocks of the Biotite-Gneiss and Schist unit consist primarily of quartz-biotite gneiss and schist, quartz-hornblende gneiss, quartz-feldspar-biotite gneiss, augen gneiss, quartz-muscovite-garnet gneiss and quartzite. This unit is exposed in the northern portion of the study area (outside the refuge boundary) in the Yukon-Tanana upland.

## Lower(?) Paleozoic

The polymetamorphic rock of the Quartz Mica Schist unit crop out at several localities north of Airs Hill, in the southeastern portion of the refuge, and along the the Chisana River. The unit reflects low to intermediate grade (greenschist facies) metamorphism and is composed chiefly of tan and light-gray quartz-muscovite schist. Highly developed schistosity obscure the original bedding. The unit may be the oldest rock exposed within the refuge boundary.

## Paleozoic

The Schist and Quartzite unit crops out on the northeast border of the refuge, near the confluence of the Nabesna and Chisana rivers. Composed chiefly of greenschist facies rocks, the unit includes quartz-sericite schist, quartzite, quartz-muscovite schist, actinolite schist, chert and other fine-grained silic rock, phyllite, meta-graywacke and schistose greenstone.

## Paleozoic (Devonian)

Marine metasedimentary rocks, described by Foster (1970) as the Phyllite and Schist unit in the Tanana Quadrangle, crop out in the northwestern section of the Black Hills. The rocks consist predominantly of dark-gray phyllite,

dark-gray to buff quartzite and calcareous quartzite, light-gray porcellanite, buff to light-gray calcareous quartz-mica schist and light-gray marble. The rocks exhibit low-greenschist metamorphic facies with local intrusions of mafic dioritic and gabbroic bodies that form sills, dikes and irregular lenses.

Dark greenish-gray mafic diorite and gabbro bodies intrude into rocks of the Phyllite and Schist unit. These rocks occur primarily as sills, dikes and small masses. Lack of foliation indicate emplacement after the main period of folding and faulting.

A sequence of regionally metamorphosed (low-greenschist facies) marine sedimentary rocks, comprised primarily of intertonguing units of phyllite, limestone, and massive greenstone of volcanic origin, occupy sections of Airs Hill in the southeast, the Black Hills in southcentral, and the Mentasta Mountains, north of Denali fault.

The Phyllite unit includes dark to light-gray phyllite and a metaconglomerate which contains conspicuous stretched clasts, subordinate quartz-mica schist, quartzite, calcareous mica schist, quartz-chlorite schist and thin marble lenses.

Numerous and prominent castles and pinnacles of recrystallized limestone protrude above the Phyllite unit, north of Denali fault in the Mentasta Mountains. Widely scattered locations of rugose and tabulated corals, identified by Richter (1976), indicate a Middle Devonian age.

Portions of the Black Hills and Airs Hill contain exposures of dark, greenish-gray massive greenstone. The rocks consist chiefly of fine-grained epidote, chlorite and altered feldspar with segregations of actinolite and small phenocrysts of clinopyroxene. Richter (1976) describes the greenstone as extrusive andesite and basalt flows, but may also be, in part, intrusive in origin.

## Mesozoic (Lower Cretaceous and Upper Jurassic)

A widespread and thick sequence of predominantly shallow and deep intertonguing marine sedimentary rocks are exposed south of Denali fault in the Mentasta-Nutzotin Mountains. They are informally referred to as the Nutzotin Mountains sequence (Berg and others, 1972). Three separate lithologic units are recognized in the main part of this sequence. These units underlie much of the terrain between the Denali fault and the Totschunda fault. Middle Cretaceous plutonic events, south of the Denali fault, have intruded each unit within the sequence. Contact between these sedimentary beds and the larger intrusions has produced banded hornfels.

The marine sequence, predominantly in fault contact with older rock, is probably more than 9,800 feet (3,000 m) thick (Richter, 1976).

The lower unit in the Nutzotin Mountains sequence, exposed west of Totschunda fault (outside the refuge), is about 4,900 feet (1,500 m) thick and consists of massive beds of shallow water pebble to cobble conglomerate up to 130 feet (40 m) thick. The conglomerate is interbedded with dark-gray siltstone and argillite that locally contain coalified wood fragments and other carbonaceous debris. Clasts in the conglomerate are believed to have originated from two sources: (1) the well rounded volcanic and volcanoclastic rocks, chert, limestone, and crystalline igneous rocks from underlying strata of the Taku-Skolai terrane (Berg, Jones, and Richter, 1972), and (2) the quartz and metamorphic rocks derived from the Yukon-Tanana terrane (Richter, 1976).

Richter (1976) determined an age of Late Jurassic based on the relative abundance of Buchia. This unit is conformably overlain by, and possibly gradational with, a sequence of nonmarine sedimentary rock.

The middle (and major) unit of the sequence consists of turbidite deposits composed of well-developed graded beds of dark gray argillite, siltstone and graywacke. These beds alternate locally with massive beds of pebble to cobble conglomerate, pebbly graywacke, graywacke and argillite. Derived from terranes north and south of the Denali fault, the conglomerates are polymictic with rounded clasts and exhibit well developed graded beds that rhythmically alternate in units 0.5 inches (1 cm) to more than a foot (30 cm) thick. The Buchia found in this unit indicate late Jurassic age. Fossils are very rare.

The upper unit of the Nutzotin Mountains sequence consists of dark-gray, graded argillite and graywacke approximately 2,950 feet (900 m) thick, overlain by 600 to 1,650 feet (180 to 450 m) of gray mudstone. The abundance of Buchia indicate Late Jurassic to Early Cretaceous age. Massive andesite breccias of the Chisana Formation conformably overlie tuffaceous mudstone beds near the top of this unit (Richter, 1976).

Structurally contorted marine sedimentary rock, exposed on four hills just north of the Denali fault in the southwest corner of the refuge, consist of dark-gray argillite, greenish-gray graywacke and argillite-siltstone-graywacke. These beds are similar to the marine sedimentary rocks of the Nutzotin Mountains sequence (KJs), south of Denali fault, and are assumed to represent gravity slide blocks off this sequence (Richter, 1976).

#### Mesozoic (Cretaceous(?))

Three thin, elongate bodies of alpine-type ultramafic rocks, consisting chiefly of serpentinite, serpentized peridotite and dunite with subordinate clinopyroxene, crop out near the eastern edge of the Black Hills and at Airs Hill near Mirror Creek. The ultramafic rocks in the Black Hills are restricted to the Devonian phyllite sequence (Dp) while the Mirror Creek ultramafic rocks intrude the Conglomerate and Sandstone sequence (TKc).



Thermally altered limestones (D1) formed as a result of their contact with the ultramafics, suggest that the ultramafics were emplaced at moderately high temperatures.

#### Mesozoic (Middle Cretaceous(?))

A linear stock of undifferentiated plutonic rocks, comprised of medium-grained, weakly foliated biotite-rich granodiorite-diorite, crop out along the eastern portion of the Black Hills. Ages for these intrusive features are not known, but the rocks are questionably related to a plutonic event of Middle Cretaceous time. They are not related to the Mesozoic plutons emplaced south of Denali fault.

#### Mesozoic (Middle Cretaceous)

Three large plutons, located north of Denali fault in the southwest and north central sections of the refuge, represent a Middle Cretaceous plutonic event emplaced 89 to 84 m.y. before present based on K-Ar dates (Richter, Lanphere, and Matson, 1975). The Tetlin phase, one of three compositional-textural phases of the Tok-Tetlin pluton, forms the bulk of the pluton just north of the Denali fault and consists primarily of porphyryitic biotite-hornblende quartz monzonite, locally gradational to biotite-hornblende granodiorite.

A gradational contact exists between the Tok phase and the Tetlin phase boundary.

The Cheslina pluton, located north of the Tetlin phase in the southwest part of the refuge, is predominantly a medium-grained biotite-hornblende granodiorite with a marginal phase of hornblende-biotite quartz diorite and minor hornblende granodiorite. The Gardiner Creek pluton, a coarse-grained,

leucocratic, biotite-quartz monzonite that locally contains minor hornblende, crops out south of the confluence of the Chisana and Tanana Rivers and outside the eastern refuge boundary.

### Tertiary or Cretaceous

Massive, thickly-bedded pebble to cobble conglomerate, conglomeratic sandstone and coarse grained sandstone containing subordinate beds of finer grained clastic rocks crop out on the hills surrounding Wellesley Mountain in the lower southwest corner of the refuge. Clasts within the subordinate beds exhibit subangular to well rounded form and consist mainly of greenstone, chert, quartz, phyllite and crystalline igneous and metamorphic rocks.

The conglomerate and sandstone beds generally dip northward at low angles and overlie older metamorphic rocks with a marked angular unconformity.

### Quaternary

Morainal deposits of the Black Hills glaciation of Illinoian age (Fernald, 1965) exhibit subdued geomorphic expression. Distribution of these deposits occurs along the length of the Black Hills and along Stuver Creek. The largest morainal remnant is located on the western edge of Stuver Creek. The drift, consisting chiefly of cobble- to boulder-size fragments in a sandy-silt matrix, contains a high percentage of basaltic and andesitic rocks characteristic of the volcanic Wrangell Mountains. Well preserved lateral, ground and end moraines of the younger (Wisconsinan age) and less extensive Jatahmund Lake glaciation, are characterized by sharp angular ridges, knobs and hollows. The drift consists of a sand and silt matrix that contains pebble- to boulder-size fragments and is interbedded with well-rounded, poorly stratified, pebble to boulder gravel. Volcanic rocks similar in lithology to those in the older drift are abundant.

Numerous deposits of undivided colluvium, comprised chiefly of rubble, gravel, sand, silt and diamicton, occur on valley walls and hill slopes throughout the higher elevations of the refuge.

High terraces along the Nabesna and Chisana rivers consist of undivided alluvial deposits which contain boulders, gravel and sand.

Lower elevations, located generally north of the Black Hills, consist of fluviolacustrine deposits which include lake, pond and low-gradient-stream deposits and, locally, abundant organic matter.

#### Structure:

The general structure of the Tetlin NWR is that of a lowland area, referred to as the Northway basin (Dibona and Kirschner, 1984) or Upper Tanana basin (Miller, 1959). The basin has accumulated Quaternary age unconsolidated glacial, glaciofluvial and fluvial deposits (Merti, 1937) several hundred feet thick (Richter, 1976). Basinal sediments, north of the Black Hills, are underlain by complexly folded and faulted Devonian and older metamorphic rocks of the Yukon-Tanana upland (Foster and others, 1976). A structural boundary may exist along the Tanana River Valley, based on geomorphic evidence of faulting. However, the presence of similar metamorphic and granitic rocks in the adjacent Northway-Tanacross lowlands, does not support the existence of such a structure (Foster and others, 1973). Several circular features, identified by satellite imagery and aeromagnetic anomalies within the Nabesna quadrangle, appear to be unrelated to Cenozoic volcanic activity of the Wrangell Mountains and may define the extent of hidden or buried intrusive bodies (Albert, 1976).

The northwest-trending, high-angle, Denali-Totschunda fault system transects the southwest corner of the refuge and forms the dominant structural feature within the study area.

The Denali fault, a right lateral strike-slip fault believed to have formed during Miocene or Pliocene time, extends in a broad arc from the Canadian border in the east to Bristol Bay in the west. The total length of the fault in Alaska is about 995 miles (1600 km) (Plafker, Hudson, and Richter, 1976). Locally, the fault marks the southern extent of the Devonian and older, highly deformed, metamorphic complex of the Yukon-Tanana Upland (Foster, 1970). Right lateral displacement along the fault is calculated at 200 miles (320 km), assuming a constant rate of motion since its formation and an average slip rate of 1 inch (2.54 cm) per year (Richter and Jones, 1972).

The younger Totschunda fault system, a right lateral splay of the Denali fault, formed during Pleistocene(?) time and extends from the Canadian border in a northwest direction for about 125 miles (200 km) (Plafker and others, 1976). Movement along the Denali fault southeast of the juncture between the two faults was redirected through the Totschunda fault system during Quaternary time. Movement along the Denali fault system northwest of the juncture has remained unchanged. Total offset for the Totschunda fault is calculated at about 6 miles (9.6 km) (Richter and Jones, 1972).

Complexly folded Cretaceous and Jurassic marine sedimentary rocks of the Nutzotin Mountains Sequence, situated almost entirely between the Denali and Totschunda faults, exhibit northwest-trending, gently-dipping axial surfaces and fault planes that generally dip steeply to the northeast (Berg, Jones, and Richter, 1972). Low angle thrust faults, high angle reverse faults and isoclinal folds, many of which are overturned, are common structural features within the middle and major unit of the sequence (Richter, 1976).

#### Tectonic Setting:

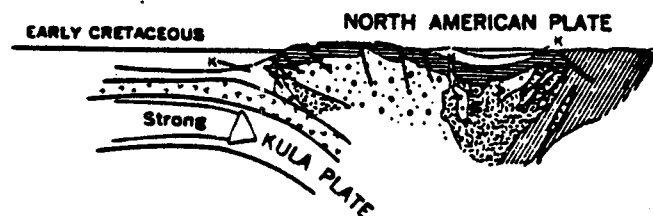
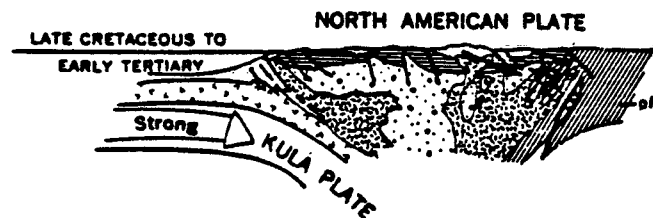
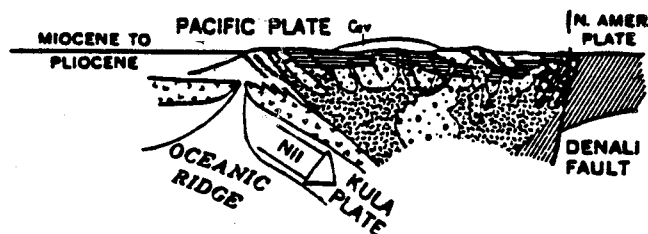
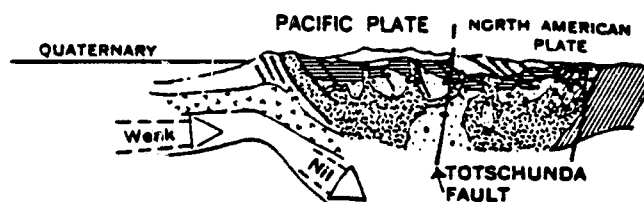
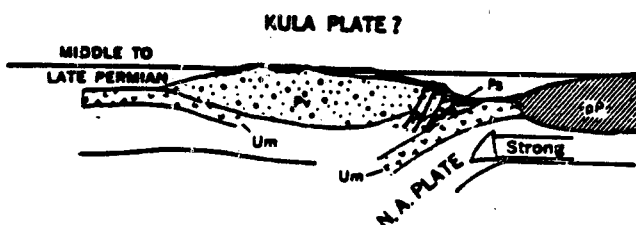
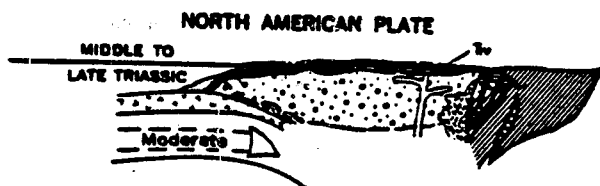
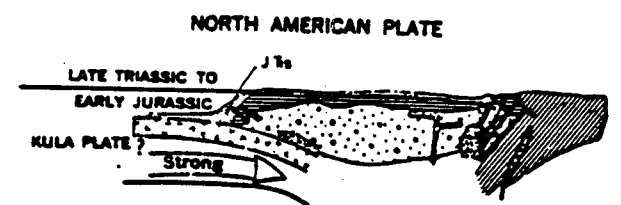
Situated approximately 200 miles (320 km) north of the Gulf of Alaska, the Tetlin Refuge lies on the southern Alaska continental margin of the North American Plate. Tectonic history and framework, important in the geological

development of the study area, differs markedly along that segment of the Denali fault which separates Devonian and older metamorphic rocks of the Yukon-Tanana Upland from Permian to Quaternary sedimentary and volcanic rocks south of the structure.

Underthrusting of an ancient, northward moving, oceanic plate (Kula Plate(?)) beneath the North American Plate during Late Permian to Early Tertiary time, resulted in the great tectonic forces responsible for the assembling of structural and deformational features south of Denali fault (Figure 5). Relief of tectonic stress occurred through regional subsidence, overthrusting, folding, uplift, and volcanic activity. Subsequent encroachment of the Pacific Ocean Plate during the Late Tertiary, brought a slight change in direction and a relative reduction in rate of motion. This new tectonic element played a major role in the formation of the Denali fault system, and later, the Totschunda fault.

The primary tectonic element of east central Alaska, north of Denali fault and south of the Yukon River, is believed to be a fold belt, termed Cordilleran fold belt by Lathram (1973), of Precambrian and Early Paleozoic age. Formed from the deposits of the Cordilleran geosyncline, a Paleozoic tectonic regime along the western edge of North America, the belt extends through the Yukon-Tanana upland. Available data on the ages of metamorphism and the polymetamorphic nature of the rocks within the upland, suggest a history of deposition and deformation during Precambrian-middle Paleozoic time (Lathram, 1973; Foster and others, 1973).

Four lithotectonic terranes run in a northwest - southeast direction across the Tetlin Refuge. A terrane, described as a fault-bounded geologic entity, is characterized by a distinct geologic history which differentiates it from adjacent terranes (Jones, Silberling, Cony, and Plafker, 1987). Figure 6 shows the location of these terranes within the study area.



#### Symbols

- pP - Pre-Permian metamorphic rocks north of Denali fault.
- Pv - Permian volcanic rocks.
- Ps - Permian sedimentary rocks.
- Tr v - Triassic volcanic rocks.
- JTr s - Jurassic and Triassic sedimentary rocks.
- Um - Ultramafics.
- g - Granitic rocks.

Figure 5 - Diagrammatic cross section through eastern Alaska Range and south-central Alaska along 142°W longitude, Permian through Quaternary. (after Berg, Jones, and Richter, 1972).

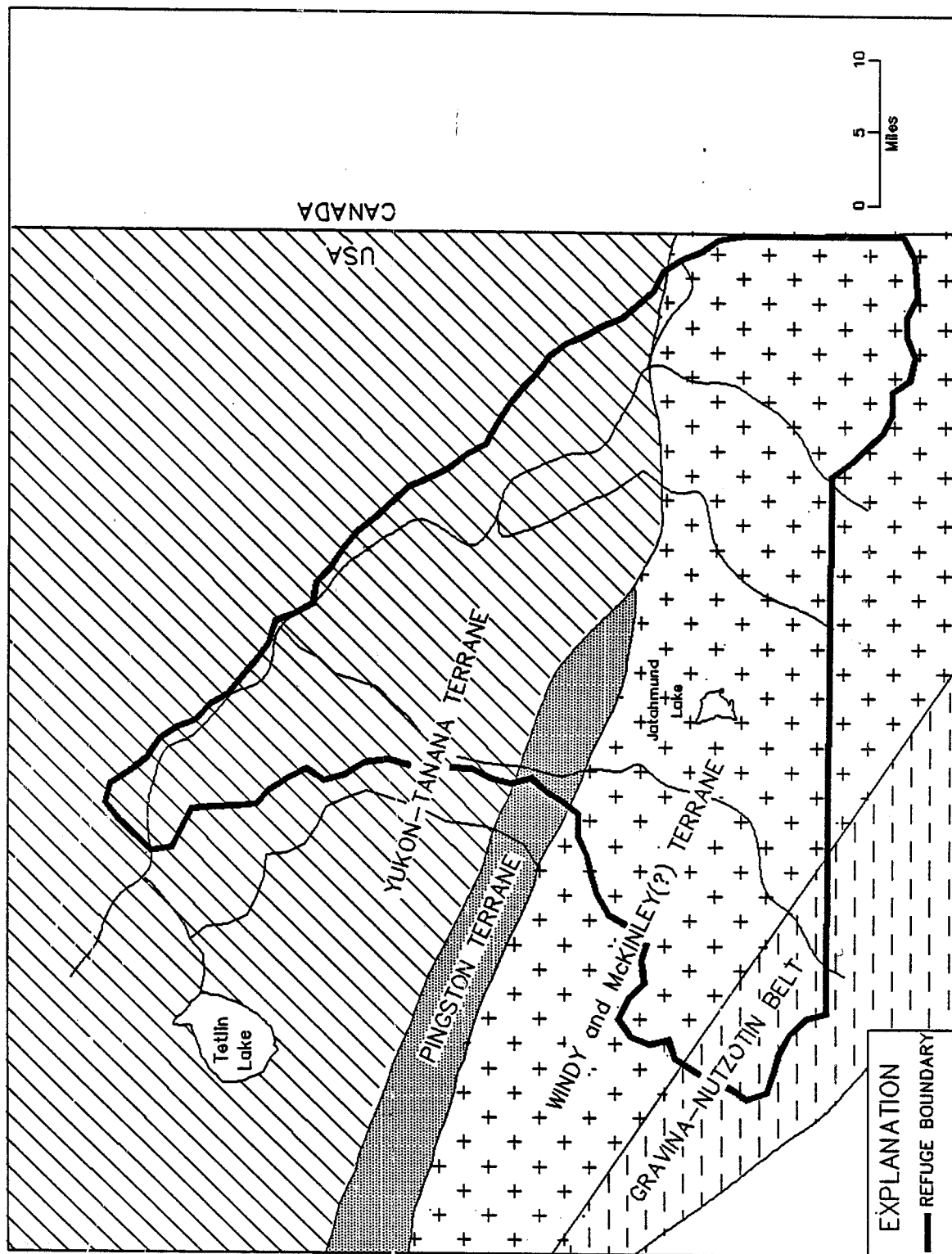


Figure 6. Lithotectonic terrane map of Tetlin NWR (after Jones, Silberling, Coney, and Plafker, 1987, and Jones, Silberling, Berg, and Plafker, 1981).

Locally, the Pingston terrane contains strongly folded, highly metamorphosed strata of upper Paleozoic phyllite, minor limestone and chert, and Upper Triassic limestone, shale, calcareous siltstone and minor quartzite (Jones and others, 1987). Large masses of gabbro and diabase of Cretaceous(?) age cut the terrane. The terrane also lacks extrusive volcanic rock and lies in fault contact with upper Mesozoic clastic rocks and Triassic basalts of the McKinley terrane. The upper Triassic rock of the Pingston terrane is composed of deep water facies containing no recognizable coarse detritus that could have been derived from the Yukon-Tanana terrane to the north (Jones and Silberling, 1979).

The McKinley terrane, with its presence in this region of Alaska questionable (Jones, Silberling, Cony, and Plafker, 1987), is composed of a poorly understood and structurally complex assemblage of rock consisting of a thick sequence of upper Paleozoic flysch deposits overlain by Triassic chert and Upper Triassic pillow basalt, gabbro and diabase.

Jones and others (1987) describe the Windy terrane as a disrupted assemblage of serpentinite, basalt, meta-chert, and blocks of Devonian limestone and shale, in a matrix of upper Mesozoic conglomerate flysch.

Deposited in a linear marine basin, the Gravina-Nutzotin belt developed largely on the Taku-Skolai terrane (Wrangellia terrane) to the south and on an unknown metamorphic source terrane(s) (Berg, Jones, and Richter, 1972). Richter (1976) believes this unknown source terrane may be the Yukon-Tanana terrane. The belt consists of Upper Jurassic to Middle Cretaceous sedimentary rocks ranging from marine turbidites to shallow-water and nonmarine deposits, as well as andesitic volcanics, tuffaceous and volcanoclastic rocks and Middle Cretaceous granitic rocks.



Berg and others (1972) postulate that the belt corresponds, at least in part, to a typical magmatic (volcanoplutonic) arc based on the presence of thick andesitic lenses of volcanic rock and cogenetic plutons. Because of the belt's great thickness of flysch-like turbidite deposits, derived in part from older, external terranes, Berg refers to the belt as a "basinal" arc. Several differences were, however, noted between the typical magmatic arc system and the Gravina-Nutzotin belt: (1) the great thickness of sedimentary rocks in the belt indicate rapid depression. Much of the belt was primarily a negative feature and not a positive one as expected in a volcanic arc, (2) the large ratio of sedimentary to volcanic rocks [estimated to be greater than 10:1], and, (3) identifiable debris in the belt's sedimentary rocks must have been derived from older terranes and are not of volcanic arc origin (Berg, Jones, and Richter, 1972).

The Yukon-Tanana terrane, a large tract of polydeformed and metamorphosed rock occupying much of east-central Alaska, is believed to be comprised of several amalgamated terranes. These terranes shared a common geologic history prior to their accretion onto North America (Jones and others, 1985). The terrane's complex metamorphic fabric and high degree of metamorphic mineral development are believed to have obscured its original stratigraphic features and relations (Jones, Blake, Howell, and Engebretson, 1985). The dominant lithology includes quartz-mica schist and gneiss, quartzite, metarhyolite, gneissic plutonic rocks and minor marble. K/Ar dating indicates a terminal metamorphic event during Late Mesozoic time (Foster, 1976; Bundtzen and Turner, 1979).

#### Geologic History:

The rocks and sediments within the study area of the Tetlin NWR, range in age from Precambrian(?) to Recent. The geologic history north and south of the Denali fault are discussed separately due to the divergent tectonic history and structural nature of these areas.

From late Precambrian thru middle or late Paleozoic, the Yukon-Tanana upland was probably a site of eugeosynclinal deposition and deformation (Foster and others, 1973; Lathram, 1973). Representing mobile areas of active interplay between continental and oceanic plates, the eugeosyncline was the precursor of the Cordilleran fold belt which extends through the Yukon-Tanana upland. The core of the belt consists of a polymetamorphic, multideformed sequence of gneiss, amphibolite, schist, marble, and ultramafic rocks (Lathram, 1973).

Subsequent uplift during the Late Devonian predates the belt's accretion onto the continental mass (Lathram, 1973). Stratigraphic sequence and isotopic age dates place major Paleozoic mountain building events during the Ordovician, Early or Middle Devonian, and the Pennsylvanian and Permian (Foster and others, 1973). Mafic volcanic and intrusive activity occurred in the Late Ordovician, Devonian, and Permian with at least some emplacement of ultramafic bodies during the Devonian. From Late Triassic to Tertiary time, the metamorphic rocks of the upland were subjected to extensive intrusion by granitic plutons composed mostly of quartz monzonite and granodiorite (Foster and others, 1976). The number of metamorphic episodes associated with the upland is not known, however, regional metamorphism did take place prior to the emplacement of the granitic intrusions. Widespread volcanic activity, which may have been associated with the igneous activity, occurred primarily in the eastern portion of the Yukon-Tanana upland during Tertiary time.

The geologic history south of Denali fault, as inferred by Richter and Jones (1973), began with the development of a volcanic island arc on the ancient oceanic Kula plate (Grow and Atwater, 1970) during Early Permian to Late Pennsylvanian time. Underthrusting of the North American plate, with a leading edge of oceanic crust, formed the arc.

By the Middle to Late Permian, the leading edge of oceanic crust migrated into the active trench bordering the arc. Impingement of the oceanic crust on the arc resulted. Marine sedimentary rocks were deposited as portions of the arc subsided. This was brought about by a decrease in volcanic activity.

Continental plate motion and subduction under the arc continued, probably through Late Permian to Middle Triassic, eventually causing the collapse of the volcanic arc onto the continental plate. This was accompanied by the emplacement of alpine-type ultramafic rocks along the suture zone as well as uplifts, heterogeneous dioritic and syenitic intrusions and local metamorphism.

As underthrusting by the North American plate waned, the oceanic plate broke along its join with the volcanic arc and began its descent under the arc now joined to the continent.

Middle to Late Jurassic age regional subsidence resulted from the outpouring of subaerial flood basalts over Permian volcanic rocks and sediments. Marine transgressional seas deposited thick, carbonate muds and thin-bedded limestone on the submerged continent.

A trench, related to the active subduction zone along the continental margin, received a thick section of clastic sediments during Jurassic and Cretaceous time. Continued compression and overthrusting of the continental margin produced intense normal and reverse faulting. The associated volcanic activity during this period probably represents the initial stages of the Middle Cretaceous plutonic events which climaxed during the Late Cretaceous or Early Tertiary.

Folding and overthrusting severely deformed the sedimentary rocks in the deep Jurassic and Cretaceous basins.

Shallow plutonic activity began in early Miocene and by the middle Miocene, large andesitic volcanoes were forming and the rift zone which separated the ancient oceanic Kula plate from the Pacific plate, disappeared into the trench. The Pacific plate did not underthrust the continent in southcentral Alaska, but instead, brought a slight change in the direction of plate motion. As a result, initial stages of the Denali-Totschunda system were activated.

Quaternary deposition within the Tetlin NWR began with two major Pleistocene glacial periods, the Black Hills glaciation of Illinoian age and the Jatahmund Lake glaciation of Wisconsinan age (Fernald, 1965).

Glaciers from both periods originated in the Wrangell Mountains and flowed northward through the Alaska Range into the lowlands and piedmont areas via the Nabesna and Chisana river valleys. Moraines left behind by these glaciers represent the last glaciation in this area.

Recent geologic events that postdate the glacial periods include:

(1) stabilization of dune sand from late Wisconsinan and post glacial times (12,400 B.P. - 6,200 B.P.), (2) organic-bearing alluvium and colluvium sediments deposited along lowland borders and tributary valleys (10,500 B.P. to present), and (3) widespread deposition of fluvial and lacustrine sediments consisting of fine-grained, organic-bearing matter (within the last 3,000 years).

#### Description of Oil and Gas Resources

##### Known Oil and Gas Fields (Regional):

Current oil and gas productions within Alaska are located in the Cook Inlet basin, southwest of Anchorage, and on the Arctic North Slope. Neither of these areas are related to the Tetlin NWR and are therefore not discussed.

#### Known Oil and Gas Fields (Local):

No known oil and/or gas fields exist within the Tetlin NWR or the surrounding area.

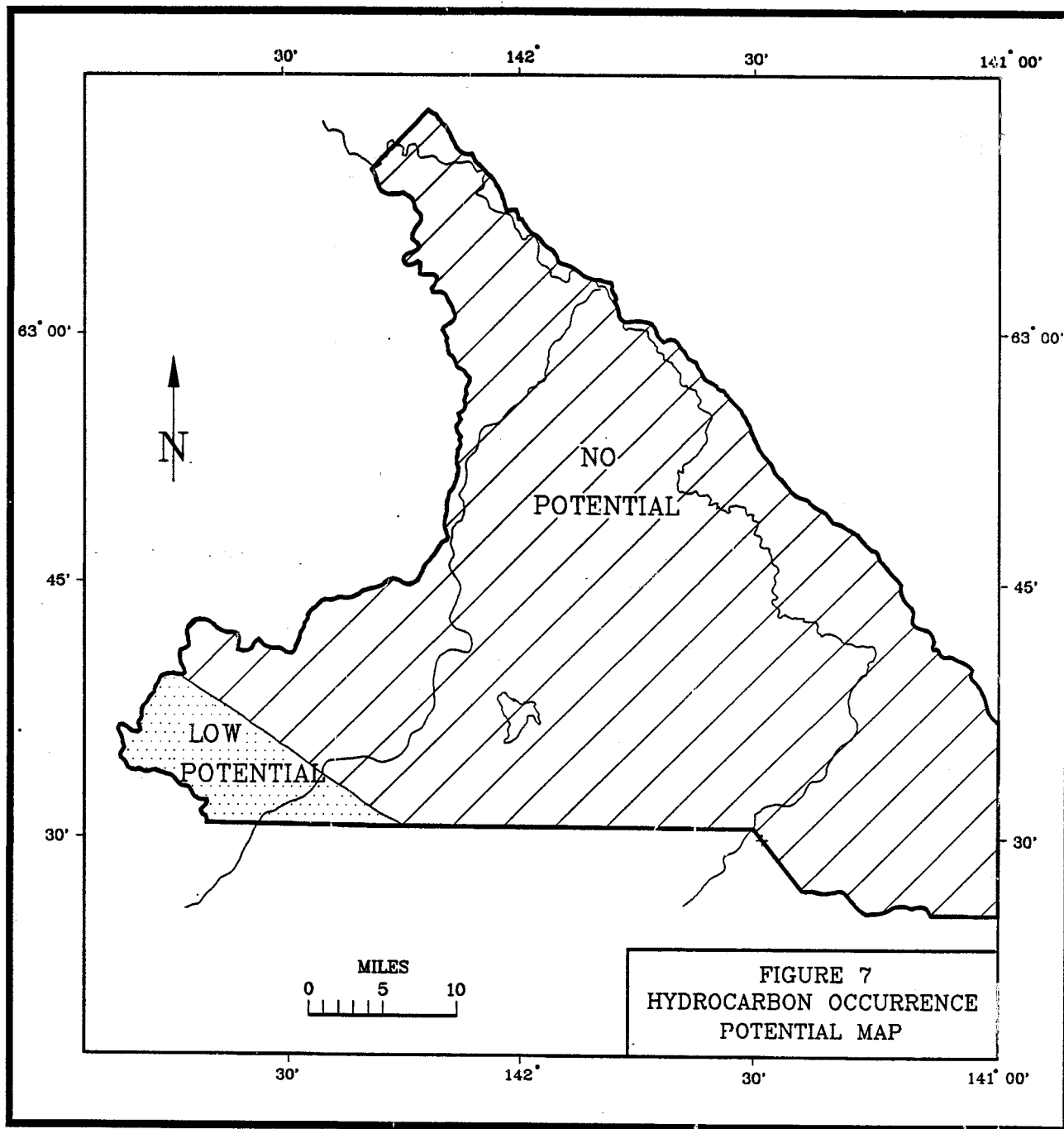
In 1955, two shallow wells, drilled in unconsolidated Quaternary deposits along the Alaska Highway, produced an unspecified amount of gas (mostly methane) after penetrating permafrost (Miller, Payne, and Gryc, 1959). The first well, located about 10 miles (16 km) northwest of the international border, found gas at 200 feet (61 m) while drilling for water. Gas was discovered between the 195- and 220-foot level (59 and 67 m) of a 350-foot (107 m) well drilled approximately 3 miles (5 km) northwest of the first. The gas from both wells may have been produced from the decay of organic matter and, therefore, biogenic in origin (Miller, Payne, and Gryc, 1959).

#### Potential for Oil and Gas Occurrence

The Tetlin NWR can be divided into two areas of oil and gas occurrence potential (Figure 7). Appendix B describes BLM's mineral potential classification system.

Late Jurassic and Early Cretaceous marine sedimentary rocks of the Nutzotin Mountains sequence, located south of Denali fault in the southwest corner of the refuge, have been classified as LOW potential for the occurrence of oil and gas (Figure 7). Occupying approximately 45,000 acres of refuge land, this area has a BLM mineral classification of L/A.

The basis for this classification stems from: (1) the lack of petrologic and geochemical information on the rocks within the Nutzotin Mountains sequence and (2) the possible existence of a massive limestone unit underlying the sequence. Specifically, turbidite deposits, which have been identified in the middle and major unit of the sequence, and limestone, are potential oil



and gas reservoirs (Sullwold, 1961). However, the indurated (compact) nature of the sedimentary rocks identified in the middle unit (i.e., argillite and graywacke) make it difficult to assess the likelihood of these rocks serving as reservoirs.

The remainder of refuge lands, approximately 879,000 acres, have been classified as having NO potential for the occurrence of a concentration of oil and gas (Figure 7). A BLM mineral classification of O/D has been assigned for this area.

This classification is based primarily on: (1) the metamorphic and igneous origin of the rocks which crop out at various locations throughout the refuge and (2) the unlikely occurrence or generation of significant oil and gas in the relatively shallow, Quaternary age, basinal sediments covering most of the refuge.

Mesozoic age conglomerates and sandstones, which crop out in the southeast portion of the refuge, could have, under the right circumstances, served as oil and gas reservoirs. However, the source rock from which the hydrocarbons would migrate, does not exist in the surrounding geologic terrane. Rocks identified in the immediate vicinity are either metamorphic or igneous and are considered to hold no potential for the generation of oil or gas.

#### Typical Oil and Gas Development Scenario

##### Production Scenario:

Since the Tetlin NWR has LOW to NO hydrocarbon occurrence potential, the scenario presented below is very generalized.

Any potential development within the refuge would most likely be a small gas deposit produced for local needs. To be economic, the prospect must be located near the gas market. Disturbance in the area would be minimal: one or two gas wells, a separator facility, a road from the field to existing infrastructure, and a parallel, small-diameter pipeline. A small office would be located on-site, but there would not be any housing modules. An estimate of the direct area disturbed by the above development would range from 10 to 20 acres and would require approximately 120,000 cubic yards of gravel (assuming gravel pads and roads would be five feet thick to protect the permafrost environment).

Oil development in the Tetlin NWR is very unlikely. A large deposit would have to be discovered to justify the expense of producing and transporting the product to a viable market. The LOW potential classification for this area indicates that discovery of such a deposit is unlikely.

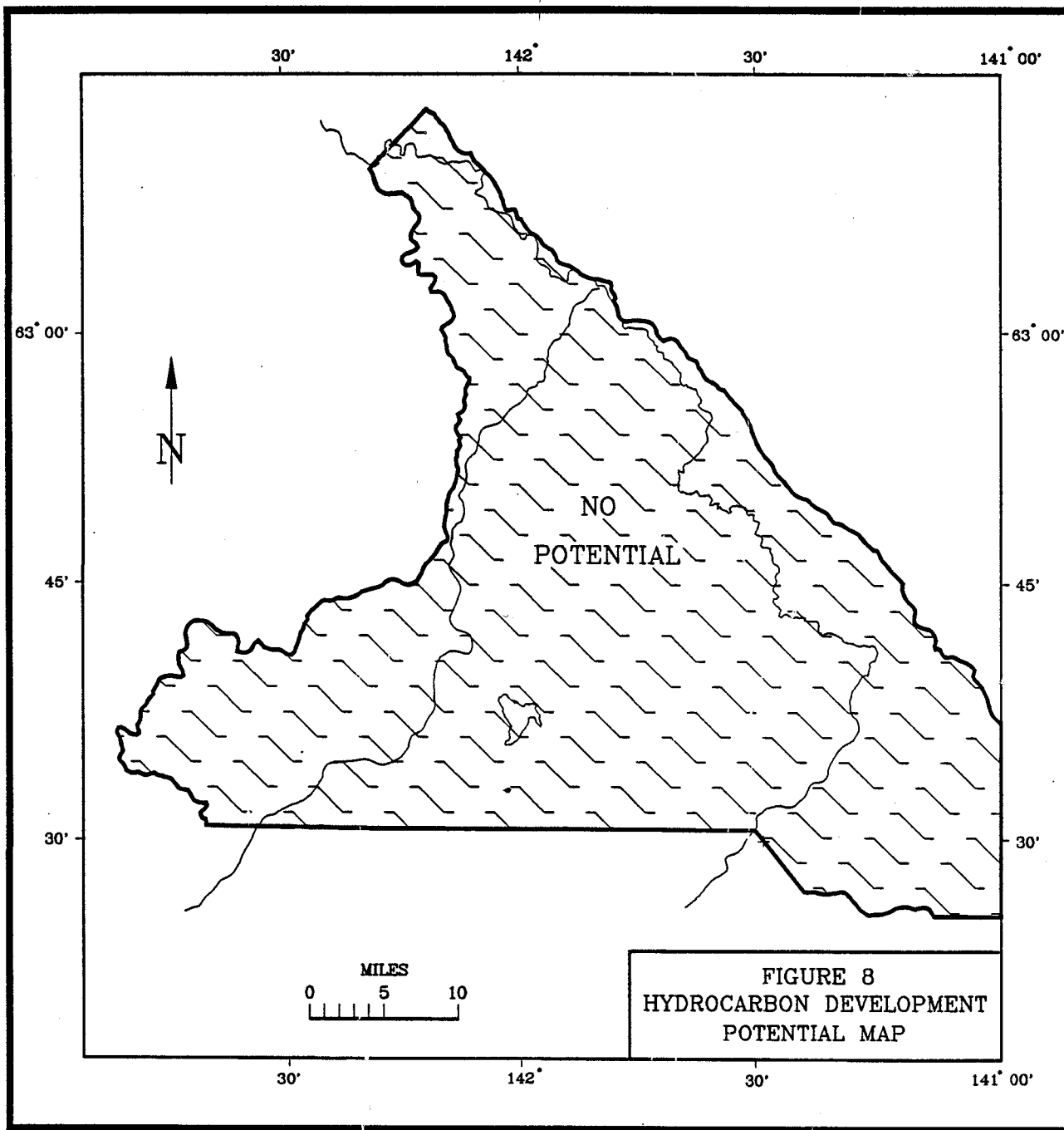
If large gas deposits were discovered, development would occur on a larger scale and could be located farther from the gas market. Assuming these parameters, one could expect a development scenario very similar to the scenario presented in the Selawik National Wildlife Refuge Oil and Gas Assessment. Facilities needed for the production would include gas wells, injection well, pipelines, and roads. Total direct acreage disturbed would range from 30 to 60 acres and would require approximately 250,000-500,000 cubic yards of gravel.

#### Economic Potential

Approximately 95 percent of the Tetlin NWR has no geologic potential for the accumulation of oil and gas resources. The remainder of the refuge (about 45,000 acres) was determined to have low geologic potential, as the data base was insufficient in both direct and indirect evidence to support or refute the existence of oil and gas resources.



The Tetlin NWR has no economic potential for the development of oil and gas resources for at least 25 years (Figure 8). This economic assessment is based on conclusions drawn from the geologic evidence coupled with: (1) the oil industry's lack of interest in the area, (2) Tetlin's remote location relative to existing oil fields, and (3) the total lack of exploratory drilling within refuge boundaries.



## Bibliography

Alaska Division of Geological and Geophysical Surveys, 1973, Aeromagnetic map, Tanacross quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-File Map AOF 11, 1 sheet, scale 1:250,000.

Alaska Division of Geological and Geophysical Surveys, 1973, Aeromagnetic map, Nabesna quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-File Map AOF 13, 1 sheet, scale 1:250,000.

Albert, N. R. D., and Steele, W. C., 1976, Interpretation of Landsat imagery of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767C, 3 sheets, scale 1:250,000.

Albert, N. R. D., and Steele, W. C., 1976, Interpretation of Landsat imagery of the Tanacross quadrangle, Alaska: U.S. Geological Survey Open-File Report 76-850, 26 p. + illustrations.

Barnes, D. F., 1975, Gravity map of the Nabesna quadrangle, Alaska, U.S. Geological Survey Miscellaneous Field Studies Map MF-655I, 1 sheet, scale 1:250,000.

Barnes, D. F., 1976, Gravity map of the Tanacross quadrangle, Alaska, U.S. Geological Survey Miscellaneous Field Studies Map MF-767B, 1 sheet, scale 1:250,000.

Berg, H. C., Jones, D. L., and Richter, D. L., 1972, Gravina-Nutzotin belt-Tectonic significance of an upper Mesozoic sedimentary and volcanic sequence in southern and southeastern Alaska: U.S. Geological Survey Professional Paper 800-D, p. D1-D24.

- Brooks, A. H., 1899, A reconnaissance in the White and Tanana River basins, Alaska, in 1898: U.S. Geological Survey 20th Annual Report, pt. 7, p. 425-494.
- Brooks, A. H., 1914, The Chisana placer district: U.S. Geological Survey Bulletin 592, p. 309-320.
- Capps, S. R., 1915, Mineral resources of the Chisana-White River district: U. S. Geological Survey Bulletin 622, p. 189-228.
- Capps, S. R., 1916, The Chisana - White River district, Alaska: U. S. Geological Survey Bulletin 630, 130 p.
- Churkin, Michael, Jr., 1973, Paleozoic and Precambrian rocks of Alaska and their role in its structural evolution: U.S. Geological Survey Professional Paper 740, 64 p.
- Churkin, Michael, Jr., Foster, H. L., Chapman, R. M., and Weber, F. R., 1982, Terranes and suture zones in east-central Alaska: Journal of Geophysical Research, v. 87, no 5, p. 3718-3730.
- Dibona P. A., and Kirschner, C. E., 1984, Geologic bibliography for selected onshore sedimentary basins of central and southern Alaska stressing basin analysis and including an index of publications on available well and surface data: U.S. Geological Survey Open-File Report 84-99, 72 p.
- Dobey, P. L., and Henning, M. W., 1973, Mineral evaluation of the D-2 land area, Nabesna quadrangle, using aeromagnetic and geochemical data: Alaska Division of Geological and Geophysical Surveys Open-File Report AOF-34, 10 p.

- Ehm, Arlen, 1983, Oil and gas basins map of Alaska: Alaska Division of Geological and Geophysical Surveys Special Report 32, 1 sheet, scale 1:2,500,000.
- Fernald, A. T., 1965, Glaciation in the Nabesna River area, upper Tanana River valley, Alaska, in Geological Survey research 1965: U.S. Geological Survey Professional Paper 525-C, p.C120-C123.
- Fernald, A. T., 1965b, Recent history of the upper Tanana River lowland, Alaska, in Geological Survey research 1965: U.S. Geological Survey Professional Paper 525-C, p.C124-C127.
- Forbes, R. B., 1976, A preliminary assessment of the mineral resource potential of the Tetlin Reserve, Alaska: Geophysical Institute, University of Alaska.
- Foster, H. L., 1970, Reconnaissance geologic map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geological Inventory Map I-593, 1 sheet, scale 1:250,000.
- Foster, H. L., and Keith, T. E. C., 1969, Geology along the Taylor Highway, Alaska: U.S. Geological Survey Bulletin 1281, 36 p.
- Foster, H. L., Weber, F. R., Forbes, R. B., and Brabb, E. E., 1973, Regional geology of the Yukon-Tanana upland, Alaska in Pitcher, M. G., ed., Arctic Geology-- proceedings of the second international symposium on arctic geology, February 1-4, 1971, San Francisco, California: American Association of Petroleum Geologists, Memoir 19, Tulsa, Oklahoma, p. 388-395.

- Foster, H. L., Albert, N. R. D., Barnes, D. F., Curtin, G. C., Griscom, Andrew, Singer, D. A., and Smith, J. G., 1976, The Alaska Mineral Resource Assessment Program: Background information to accompany folio of geologic and mineral resource maps of the Tanacross quadrangle, Alaska: U.S. Geological Survey Circular 734, 23 p.
- Gabrielse, H., 1967, Tectonic evolution of the Northern Canadian Cordillera: Canadian Journal of Earth Science, v. 4, p. 271-298.
- Gates, G. O., and Gryc, G., 1963, Structure and tectonic history of Alaska, in Childs, O. E., and Beebe, B. W., eds., Backbone of the Americas--Tectonic History from Pole to Pole, a symposium: American Association of Petroleum Geologists Memoir 2, p. 264-277.
- Grantz, A., 1966, Strike-slip faults of Alaska: U.S. Geological Survey Open-File Report 66-53, 82 p.
- Griscom, Andrew, 1976, Aeromagnetic map and interpretation of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767A, 2 sheets, scale 1:250,000.
- Grow, John, and Atwater, Tanya, 1970, Mid-Tertiary tectonic transition in the Aleutian arc: Geological Society of America Bulletin, v. 81, no. 12, p. 3715-3721.
- Jones, D. L., Blake, M. C. Jr., Howell, D. G., and Engebretson, D. C., 1985, Applications of tectonostratigraphic terrane analysis to Alaska: Alaska Geological Society.
- Jones, D. L., Cox A., Coney, P., and Beck, M., 1982, The growth of North America: Science America 247 (5), p. 70-84.

- Jones, D. L., and Silberling, N. J., 1979, Mesozoic stratigraphy--The key to tectonic analysis of southern and central Alaska: U.S. Geological Survey Open-File Report 79-1200, 37 p.
- Jones, D. L., Silberling, N. J., Berg, H. C., and Plafker, George, 1982, Tectonostratigraphic terrane map of Alaska, in Coonrad, W. L., ed., U.S. Geological Survey in Alaska--Accomplishments during 1980: U.S. Geological Survey Circular 844, p. 1-5.
- Jones, D. L., Silberling, N. J., Coney, P. J., and Plafker, George, 1987, Lithotectonic terrane maps of Alaska (west of the 141st meridian): U.S. Geological Survey Misc. Field Studies Map MF-1874-A, 1 sheet, scale 1:2,500,000.
- King, P. B., 1969, The tectonics of North America--a discussion to accompany the tectonic map of North America, scale 1:5,000,000: U.S. Geological Survey Professional Paper 628, 94 p.
- Lathram, E. H., 1973, Tectonic framework of northern and central Alaska, in Pitcher, M. G., ed., Arctic Geology-- proceedings of the second international symposium on arctic geology, February 1-4, 1971, San Francisco, California: American Association of Petroleum Geologists, Memoir 19, Tulsa, Oklahoma, p. 351-360.
- Mendenhall, W. C., 1900, A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U.S. Geological Survey 20th Annual Report, pt. 7. p. 265-340.
- Mendenhall, W. C., 1905, Geology of the central Copper River region, Alaska: U.S. Geological Survey Professional Paper 41, 133 p.

- Mendenhall, W. C., and Schrader, F. C., 1903, The mineral resources of the Mount Wrangell district, Alaska: U.S. Geological Survey Professional Paper 15, 71 p.
- Mertie, J. B., Jr., 1937, The Yukon-Tanana region, Alaska: U.S. Geological Survey Bulletin 872, 276 p.
- Miller, D. J., Payne, T. G., and Gryc, George, 1959, Geology of possible petroleum provinces in Alaska: U.S. Geological Survey Bulletin 1094, 131 p.
- Moffit, F. H., 1938, Geology of the Slana-Tok district, Alaska: U.S. Geological Survey Bulletin 904, p. 1-54.
- Moffit, F. H., 1941, Geology of the upper Tetling River district, Alaska: U.S. Geological Survey Bulletin 917-B, p. 115-157.
- Moffit, F. H., 1943, Geology of the Nutzotin Mountains, with a section on the igneous rocks, by R. G. Wayland: U.S. Geological Survey Bulletin 933-B, p. 103-174.
- Moffit, F. H., 1954, Geology of the eastern part of the Alaska Range, and adjacent area: U.S. Geological Survey Bulletin 989-D, p. 63-218.
- Nokleberg, W. G., Schwab, C. E., Miyacka, R. T., and Buhrmaster, C. L., 1981, Stratigraphy, petrology, and structure of the Pingston terrane, Mount Hayes C-5 and C-6 quadrangles, eastern Alaska Range, Alaska: U.S. Geological Survey Circular 868, p. 70-73.
- Payne, T. G., 1955, Mesozoic and Cenozoic tectonic elements of Alaska: U.S. Geological Survey Miscellaneous Geological Investigations Map I-84.



- Pewe, T. L., Burbank, Lawrence, and Mayo, L. R., 1967, Multiple glaciation in the Yukon-Tanana upland, Alaska: U.S. Geological Survey Miscellaneous Geological Investigations Map I-507, 1 sheet, scale 1:500,000.
- Pewe, T. L., 1975, Quaternary geology of Alaska: U.S. Geological Survey Professional Paper 835, 145 p. 3 sheets, scale 1:5,000,000.
- Plafker, G., Hudson, P., and Richter, D. H., 1976, Preliminary observations on Late Cenozoic displacements along the Totschunda-Denali fault systems: U.S. Geological Survey Circular 751-B, p. 67-69.
- Ragan, D. M., and Hawkins, J. W., Jr., 1966, A polymetamorphic complex in the eastern Alaska Range: Geological Society of America Bulletin v. 77, p. 597-604.
- Rice, D. D., and Claypool, G. E., 1981, Generation, accumulation, and resource potential of biogenic gas: American Association of Petroleum Geologists Bulletin, v. 65, no. 1, p. 5-25.
- Richter, D. H., 1967, Geology of the upper Slana-Mentasta Pass area, southcentral Alaska: Alaska Division of Mines and Minerals Geological Report 30, 25 p.
- Richter, D. H., 1975, Geologic map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655A, 1 sheet, scale 1:250,000.
- Richter, D. H., Albert, N. R. D., Barnes, D.F., Griscom, Andrew, Marsh, S. P., and Singer, D. A., 1975, The Alaska Mineral Resource Assessment Program: Background information to accompany folio of geologic and mineral resource maps of the Nabesna quadrangle, Alaska: U.S. Geological Survey Circ. 718, 11 p.

- Richter, D. H., and Jones D. L., 1973, Structure and stratigraphy of eastern Alaska Range, Alaska, in Pitcher, M. G., ed., Arctic Geology--proceedings of the second international symposium on arctic geology, February 1-4, 1971, San Francisco, California: American Association of Petroleum Geologists, Memoir 19, Tulsa, Oklahoma, p. 408-420.
- Richter, D. H., Lanphere, M. A., and Matson, N. A., Jr., 1975, Granitic plutonism and metamorphism, eastern Alaska Range, Alaska: Geological Society of America Bulletin, v. 86, no 6, p. 819-829.
- Richter, D. H., and Matson, N. A., Jr., 1971, Quaternary faulting in the eastern Alaska Range: Geological Society of America Bulletin, v. 82, no 6, p. 1529-1540.
- St. Armand, Pierre, 1957, Geological and geophysical synthesis of the tectonics of portions of British Columbia, the Yukon Territory and Alaska: Geological Society of America Bulletin, v. 68, no. 10, p. 1343-1370.
- Sullwold, Harold H., Jr, 1961, Turbidites in oil exploration in geometry of sandstone bodies--A symposium, 45th annual meeting, Atlantic City, N. J., April 25-28, 1960: American Association of Petroleum Geologists, p. 63-81.
- Tempelman-Kluit, D. J., 1975, Relationships of plutonic rocks in the Yukon crystalline terrane (abs.): Geological Association of Canada, Programme and Abs., Cordilleran Sec., p. 22-23.
- Tempelman-Kluit, D. J., Gorgey, S. P., and Reed, B. C., 1976, Stratigraphy and structural studies in the Pelly Mountains, Yukon Territory, Canada Geological Survey Paper 76-1A, p. 97-106.
- Tempelman-Kluit, D. J., and Wanless, R. K., 1975, Potassium-argon age determinations of metamorphic and plutonic rocks in the Yukon crystalline terrane: Canadian Journal of earth Sciences, v. 12, no. 11, p. 1895-1909.

U.S. Geological Survey, 1899, Maps and descriptions of routes of exploration in Alaska in 1898, with general information concerning the Territory: U.S. Geological Survey Special Publication 138, 138 p.

Wahrhaftig, Clyde, 1965, Physiographic divisions of Alaska: U.S. Geological Survey Professional Paper 482, 52 p.

APPENDIX A

MEMORANDUM OF UNDERSTANDING  
BETWEEN THE  
FISH AND WILDLIFE SERVICE  
AND THE  
BUREAU OF LAND MANAGEMENT  
U.S. DEPARTMENT OF THE INTERIOR

BACKGROUND:

Section 1008 of the Alaska National Interest Lands Conservation Act (ANILCA) requires the Secretary of the Interior to initiate an oil and gas leasing program on the federal lands of Alaska; it exempts, ". . . those units of the National Wildlife Refuge System where the Secretary determines, after having considered the national interest in producing oil and gas would be incompatible with the purpose for which such unit was established." Section 1008 also mandates that:

"In such areas as the Secretary deems favorable for the discovery of oil or gas, he shall conduct a study, or studies, or collect and analyze information obtained by permittees authorized to conduct studies under this section, of the oil and gas potential of such lands and those environmental characteristics and wildlife resources which would be affected by the exploration for and development of such oil and gas."

Section 304(g) of ANILCA requires that the Secretary of the Interior prepare a "comprehensive conservation plan" for each of the 16 National Wildlife Refuges in the State of Alaska. Among other things, these plans are to, ". . . specify the uses within each such area which may be compatible with the major purposes of the refuge." The U.S. Fish and Wildlife Service (FWS) has the responsibility for preparing the refuge comprehensive conservation plans and is using the refuge planning process to define those areas on refuges where oil and gas exploration and development may be compatible with the purposes for which each refuge was established.

PURPOSE:

To fully comply with Section 1008 of ANILCA (i.e., to consider the national interest in producing oil and gas from refuge lands) an accurate defensible oil and gas resource assessment should be prepared for each National Wildlife Refuge in Alaska. The FWS has limited technical expertise in assessing mineral potentials. However, this expertise does exist within the U.S. Bureau of Land Management (BLM). The purpose of this memorandum is to establish

cooperative procedures between the FWS and the BLM for the mutual responsibility of assessing the oil and gas potential of National Wildlife Refuge lands in Alaska.

IT IS MUTUALLY AGREED THAT:

The BLM will develop an oil and gas resource assessment for each of the 16 National Wildlife Refuges in the State of Alaska. These assessments will consist of the following items (to the extent that available data permits):

1. A detailed narrative discussion of the geologic character of the refuge.
2. A map showing all known geologic formations and geologic features pertinent to the mineral assessment.
3. A geologic cross section showing the subsurface character of the study area.
4. A detailed discussion of the engineering aspects, if there is a potential for development in the area, including the types of facilities and the infrastructure necessary to economically develop the hydrocarbon potential.
5. A generic development scenario map that will graphically portray the facilities and infrastructure discussed in item 4 above.
6. An economic assessment that will include:
  - a. a brief overview of the national energy situation and discussion of the importance of Alaskan oil and gas production.
  - b. a generalized discussion of the economic potential for oil and gas production from the refuge being evaluated.
  - c. a discussion of the factors that may affect future oil and gas development on the refuge.

The above six items shall be considered the minimum elements to be included in any refuge assessment. If sufficient nonproprietary geological and geophysical data exist, and the hydrocarbon resources warrant further description, some or all of the following items (time permitting) will also be included in the resource assessment:

- a. structural contour maps showing the location and surface areas of potential mineral occurrences,
- b. maps showing the magnetic and/or gravity character of the area,
- c. maps showing the thickness of identified rock formations,

- d. reservoir character map showing the porosity, water saturation, and permeability characteristics of potential reservoirs, and
- e. a detailed development scenario map showing roads, docks, pipeline corridors, etc. required to develop the prospects.

In preparing the oil and gas resource assessments, the BLM shall make use of (1) existing literature, (2) geological and geophysical information and data collected from FWS lands by industry permittees (see Memorandum of Understanding between FWS and BLM dated August 1984--attachment 1), and (3) geological and geophysical information and data collected on or adjacent to FWS lands by the BLM, the U.S. Geological Survey, the State of Alaska, and other government agencies. During the evaluation process, BLM geologists will make official contacts with mineral companies that may have an interest in the area. These companies will be given an opportunity to submit data for consideration and they will also be given the opportunity to discuss their feelings on the study area and its oil and gas development potential with the evaluating geologists. All interactions will be documented and submitted to the Fish and Wildlife Service at the close of the project.

The oil and gas resource assessments prepared by BLM will be delivered to the FWS in form suitable for public release. These assessments will be public documents, and the FWS will make copies of the assessments available for public review. All formal communications with the public concerning the management of FWS lands (e.g., the opening of refuge lands to oil and gas exploration or development) will be the responsibility of the FWS.

In developing the oil and gas assessment, proprietary information that was obtained by the BLM will be shared with the FWS as support for statements made in the assessment; however, proprietary information will not be included in the public report.

The number of refuge resource assessments that BLM will complete each year and the amount of funding that FWS will provide to BLM will be determined on an annual basis by mutual agreement. The following three goals have been established to assist the FWS and the BLM in planning their work commitment for completing the refuge oil and gas assessments:

1. The Becharof, Alaska Peninsula, Yukon Flats and Kenai National Wildlife Refuge oil and gas assessments will be completed during the 1986 fiscal year.
2. If at all possible, the oil and gas assessments for the remaining 12 refuges will be completed during the 1987 and 1988 fiscal years.
3. The FWS will reimburse the BLM for completion of oil and gas assessments and FWS will prioritize the assessments to be completed each year, with consideration for concurrently conducting analyses, if possible, on refuges in similar geographic location or of similar geologic character.

However, nothing in this MOU shall be construed as requiring either agency to assume or expend any funds in excess of appropriations available. The remaining 12 National Wildlife Refuge (NWR) resource assessments will be conducted in the priority order established by the FWS on an annual basis:

- |                    |                         |
|--------------------|-------------------------|
| 1. Togiak NWR      | 7. Innoko NWR           |
| 2. Tetlin NWR      | 8. Selawik NWR          |
| 3. Kanuti NWR      | 9. Kodiak NWR           |
| 4. Yukon Delta NWR | 10. Alaska Maritime NWR |
| 5. Koyukuk NWR     | 11. Izembek NWR         |
| 6. Nowitna NWR     | 12. Artic NWR           |

Amendments to this agreement may be proposed by either party and shall become effective upon mutual approval. Meetings to discuss the MOU may be called by the FWS Regional Director or the BLM State Director.

/s/ Robert E. Gilmore  
Regional Director  
U.S. Fish and Wildlife Service

3/17/86  
Date

s/ Michael J. Penfold  
State Director  
Bureau of Land Management

2/26/86  
Date

MEMORANDUM OF UNDERSTANDING  
BETWEEN THE  
FISH AND WILDLIFE SERVICE  
AND THE  
BUREAU OF LAND MANAGEMENT  
U.S. DEPARTMENT OF THE INTERIOR

ARTICLE 1 Background and objectives

Jointly, the Fish and Wildlife Service (FWS) and the Bureau of Land Management (BLM) share responsibility to help meet Department of the Interior objectives in Section 1008 of the Alaska National Interest Lands Conservation Act (ANILCA), of December 1980. The FWS is authorized to issue permits for the study of oil and gas on national wildlife refuges; the BLM may analyze resulting data for identification of potential.

The FWS is issuing permits for surface geology on all refuges. Permits for geophysical exploration may be issued on refuges having approved Comprehensive Conservation Plans. Data from both activities are required to be furnished to the FWS.

This Memorandum of Understanding is entered into to initiate the role of BLM to accept such data from FWS and be responsible for its confidentiality.

ARTICLE 2 Statement of work

The FWS agrees to deliver to BLM data collected from permittees of oil and gas studies provided for in Section 1008 of ANILCA. The BLM agrees to accept the data, store it, and keep it confidential.

ARTICLE 3 Term and modification

This understanding shall continue from date of signature ten years hence. It may be modified and/or extended by mutual agreement, and terminated by either party with sixty day's notice.

<u>/s/ Robert E. Putz</u>	<u>8/8/84</u>
Regional Director	Date
Fish and Wildlife Service	

<u>/s/ Michael J. Penfold</u>	<u>8/27/84</u>
State Director	Date
Bureau of Land Management	



## APPENDIX B

### BLM's Mineral Potential Classification System (from BLM Manual, Chapter 3131)

#### Mineral Potential Classification System

##### I. Level of Potential

- O. The geologic environment, the inferred geologic processes, and the lack of mineral occurrences do not indicate potential for accumulation of mineral resources.
- L. The geologic environment and the inferred geologic processes indicate low potential for accumulation of mineral resources.
- M. The geologic environment, the inferred geologic processes, and the reported mineral occurrences or valid geochemical/geophysical anomaly indicate moderate potential for accumulation of mineral resources.
- H. The geologic environment, the inferred geologic processes, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, and the known mines or deposits indicate high potential for accumulation of mineral resources. The "known mines or deposits" do not have to be within the area that is being classified, but have to be within the same type of geologic environment.
- ND. Mineral(s) potential not determined due to lack of useful data. This notation does not require a level-of-certainty qualifier.

##### II. Level of Certainty

- A. The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within a respective area.
- B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.
- C. The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.
- D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

For the determination of No Potential, use O/D. This class shall be seldom used, and when used it should be for a specific commodity only. For example,

if the available data show that the surface and subsurface types of rock in the respective area is batholithic (igneous intrusive), one can conclude, with reasonable certainty, that the area does not have potential for coal.

As used in this classification, potential refers to potential for the presence (occurrence) of a concentration of one or more energy and/or mineral resources. It does not refer to or imply potential for development and/or extraction of the mineral resource(s). It does not imply that the potential concentration is or may be economic, that is, could be extracted profitably.